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SOLAR ENERGY IN LATIN AMERICA

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I. INTRODUCTION

The present author's experience concerns mainly the photovoltaic conversion of solar energy. Consequently this contribution refers essentially to this field. However a few words concerning solar thermal conversion research and applications will help to judge its importance.

There is a considerable activity in solar thermal conversion in Latin America. Almost all types of technologies are being investigated by more than a hundred groups of variable size and experience. A good idea of these activities can be obtained from the proceedings of the 5th Latin American Congress on Solar Energy, held in Valparaiso, Chile, October 1986. Solar thermal collectors for water heating at domestic level are used in almost all Latin American countries. These collectors are manufactured by more than a hundred local companies of variable size. Nevertheless many of them experience commercial difficulties due to: i) a lack of strong official backing programmes for the use of solar energy (either at a residential level or at an industrial one) and ii) insufficient mature technology. A special programme for the appraisal of the problem is recommended.

Photovoltaic (PV) technology is by origin strongly related to the semiconductor electronic industry. In both cases research and development experience a difficult start in most developing countries where well trained people and specialists are seldom existent.

The analysis of the research activities in Latin American universities and research institutions, where most of the existing work is being done, shows that in many of them exists a deficient scientific leadership. Researchers, students and technicians are in general highly motivated and hard working people, the full

potential of which is not being used because of the abovementioned limitation and by the lack of clearly established sound research objectives.

Once the main investment in laboratory equipment has been made, the group faces a heavy bureaucracy for importing spare parts, special gases, chemical reagents and similar inexpensive and fundamental items. These cumbersome bureaucratic procedures tend to discourage the researchers and to break the necessary continuity of the research effort. The result of this situation is that the scientific output/input ratio is low for the Region, i.e. the scientific production as measured by international publications, patents, technical reports, etc., is not commensurate to the investments in research facilities and salaries.

Whithin this context the importance of both, human resources formation and the existence of dynamic purchasing mechanisms become clear. Meanwhile it is the author's opinion that the availability of PV specialists and trained technicians is the key issue for the future of photovoltaics in Latin America.

At present, investment in solar industry is not good business not only in developing countries but in advanced countries as well. Meanwhile it is also true that an industrial effort should be made if the future energy needs of mankind are to be satisfied. In industrialized countries solar PV programmes were established soon after the first oil crisis, their common characteristic being a strong government backing in the form of subsidies and markets for the production of this infant industry. These national programmes do not exist in Latin American countries. The necessity appears for the establishment of clear PV application programmes at national and regional level that will encourage productive activities in the field as well as the identification of the local energy problems that might be solved through the use of solar PV.

II. PV RESEARCH AND DEVELOPMENT ACTIVITIES:

The following description is certainly not exhaustive. It is based on personal contacts, visits to laboratories in different countries and the analysis of publications and contributions to international and regional PV conferences. Anyhow it represents a rather good description of the main activities being held in the Region. Research groups working on photovoltaic materials and devices exist in: Brazil, Mexico, Argentina, Colombia, Venezuela and Cuba.

BRAZIL

1. Laboratory of Photovoltaic Conversion, Institute of Physics, Campinas State University (UNICAMP), Campinas, SP.

This research group started their PV activities in Brazil in 1979. By its size and experience it is the most important research group in advanced PV materials and technologies in Latin America. The group has developed technologies on single crystal solar cells, MIS silicon solar cells and amorphous p-i-n solar cells. The main research activities refer to amorphous materials of photovoltaic interest: a-Si:H, a-$Si_{1-x}C_x$:H, a-SiN_x:H, a-$Si_{1-x}Ge_x$:H, a-GeN_x:H and transparent electrodes: SnO_2, Indium Tin Oxide, etc. In the last five years the Laboratory produced more than 25 scientific international publications, 50 communications and a dozen technical reports. Other important fields of work are: polycrystalline solar cells from up-graded metallurgical silicon, modelization of crystalline and amorphous solar cells and socio-economic aspects of solar energy conversion. The group is composed of five senior researchers, eight post-graduate students and three technicians. It has strong scientific relations with American and European laboratories and cooperates with other research groups in Argentina, Colombia and Brazil.

2. Microelectronic Laboratory, Polytechnic School, University of São Paulo, S.P.

The group started their activities in 1981 and is more engineering oriented. The main research activities are in single crystal, polycrystalline and amorphous silicon cells, as well as in transparent electrodes. One senior researcher and ten post graduate students, engineers and technicians comprise the team. The group has close contacts with other Brazilian research groups and with the University of Lisbon in Portugal. Several publications of international level have been produced in the last years.

3. Department of Metallurgy, COPPE, University of Rio de Janeiro, R.J.

The PV activities of this group started some four years ago and essentially refer to the study of surfaces and interfaces of amorphous materials and devices. The team perform research on the properties of a-Si:H and on the formation of silicides onto a-Si:H films. One senior researcher and half a dozen junior researchers and post-graduate students carry out this activity in strong interaction with well known German research laboratories and Brazilian groups. Their activities are more oriented to materials science than to PV devices.

4. Department of Metallurgy, Engineering Military Institute, Rio de Janeiro, R.J.

This group started as a thin film research group more than ten years ago. It is composed of one senior researcher and nearly half a dozen post-graduate students and technicians. The main activity up to now has been the study of II-VI semiconductor compounds and devices. Recently some research activities on InP have been performed.

5. Department of Physics, Fluminense State University, Niteroi, R.J.

The research activity related to photovoltaics consists of theoretical work on the electronic structure of a-Si:H and amorphous silicon alloys performed by two senior researchers. They work in close cooperation with the PV Conversion Lab. of UNICAMP.

6. Faculty of Engineering, Pernambuco State University, Recife, Pe.

A small team exists performing PV engineering work on systems and concentrators.

MEXICO

1. Department of Electrical Engineering, Center for Advanced Studies, National Polytechnic Institute, Mexico City, D.F.

This is probably the oldest photovoltaic group in Latin America. Their activities started at the end of the sixties and have been oriented towards the development of single crystal and polycrystalline silicon solar cell technology. A small crystalline silicon solar cell manufacturing pilot plant was established five years ago and the PV modules produced there are used to power stand-alone systems in isolated villages (mainly for illumination and communication systems). Research work on CdS, chemically sprayed SnO_2, hydrogenation effects on polycrystalline silicon solar cells and GaAs epi-layers grown by close spaced vapor transport have been made. Some solar cell modeling work is also done and recently an a-Si:H program has started. The size of the research team varied over time but was normally composed of three senior researchers and half a dozen engineers and technicians working at the pilot plant. Three to four graduate students work for their MSc or PhD degree in activities related to PV.

2. Department of Physics, Center for Advanced Studies, National Polytechnic Institute. Mexico City, D.F.

During the last years some experimental research on CdTe has been performed.

3. Institute for Materials Research, National Autonomous University, Mexico City, D.F.

A small research group on a-Si:H films and devices started their activities a few years ago. Some economic studies on PV applications have also been made as well as theoretical studies on the electronic structure and vibrational properties of amorphous semiconductors. Recently the group split into two parts, one of them moving to Temixco, near Mexico City where a new Solar Energy Research Institute has been established. Approximately twelve researchers and students are working in both groups.

ARGENTINA

1. National Institute for Chemical Technology, Santa Fe.

A research team oriented towards PV materials and devices started their activities five years ago with pretty good research facilities. Some work has been done on a-Si:H films produced by D.C. magnetron sputtering. There is also some theoretical work being done on the electronic structure of and defects in a-Si:H as well as on the modelization of polycrystalline/ amorphous silicon heterojunction. Recently the group started a glow discharge-produced a-Si:H programme in cooperation with the Photovoltaic Conversion Laboratory, Unicamp, Brazil. The group size is about six researchers and students.

2. Atomic Energy Commission, Buenos Aires.

A project for the establishment of a crystalline silicon solar cell production plan involves six researchers and engineers. They are involved with the engineering aspects of solar cell production. The project received some support from UN but it is still in a preliminary stage.

COLOMBIA

1. Department of Physics, National University, Bogota.

Research work on $Cu_2S/(ZnCd)S$ Solar Cells. Group size unknown.

2. Department of Physics, Del Valle University, Cali.

A small research group is starting activities in a-Si:H film deposition and characterization in cooperation with the Photovoltaic Conversion Laboratory of Unicamp, Brazil. Group size; five researchers and students.

VENEZUELA

1. Simon Bolivar University, Caracas.

Studies on spray pyrolized ZnO and also on CdS/CdTe heterojunctions. Group size and composition unknown.

2. Venezuelan Institute of Scientific Research, Caracas.

Material science group working for several years on ternary and quaternary semiconductors compounds of photovoltaic interest. Present group size unknown.

CUBA

1. Institute for Technical Research (ININTEF), Habana.

Some PV activity exists in this institution on concentrators for silicon solar cells. No information available on group size and other activities.

III. INDUSTRIAL PV ACTIVITIES

Apart from the already mentioned pilot plant manufacturing crystalline solar cells in the National Polytechnic Institute in Mexico there are two other industrial photovoltaic activities, one in Brazil and one in Argentina.

BRAZIL - Heliodinâmica S.A.

Heliodinâmica represents one of the most important industrial activity in photovoltaics in the Third World.

Established in 1980 the company manufactures, with Brazilian technology, single crystal silicon ingots and wafers, crystalline silicon solar cells, PV modules and systems.

1. Silicon ingots (Czochralski method, up to 8" diameter) full prodution capacity: 34 tons/years.
2. Silicon wafers (unpolished, up to 8" diameter) full production capacity: 1.2 million wafers/year.
3. Silicon wafers (polished, up to 6" diameter) full production capacity: 150.000 wafers/year.
4. Photovoltaic cells and modules (4" diameter cells) full production capacity: 1 MWp/year.

The company is currently exporting silicon wafers to the USA, Argentina, India and other countries. To a lesser extent Heliodinâmica exportsalso solar cells, PV modules and systems.

In a recent study financed by the World Bank and performed by Halcrow and Partners on the performance of commercial PV water pumping systems, Heliodinâmica and a Danish company were, out of 62 international manufacturers, the only two that satisfied the quality requirements imposed by the Bank.

ARGENTINA - Solartec S.A.

At present Solartec is encapsulating silicon solar cells from Heliodinâmica, Brazil, whithin a technology transfer agreement that foresees the fabrication in Argentina of PV modules and systems with (partially) Brazilian technology.

IV. COOPERATION PROGRAMMES AND RECOMMENDATIONS.

As already pointed out there exists a great diversity of situations concerning photovoltaic R&D in Latin American countries . Consequently, the policies tending to increase this activity have to consider the specific cases. A detailed general survey has to be done to appraise the present research objectives of the different groups and the main difficulties they experience to attain them.

The global situation allows ,however, proposal of some general cooperation schemes which will depend on the specific cases being considered.

A. Human Ressources

The lack of PV specialists is one of the major deficiencies of the Region, preventing the establishment of solid research groups that might be the origin or support for local industries. Special programmes should be organized with external cooperation to palliate this deficiency.

1. Scholarships for Latin American researchers allowing their training in PV advanced technologies. These scholarships should be granted however on the basis of well defined PV programmes in local laboratories, i.e. they should be part of a broader effort to develop PV activities.

2. Visits of well known PV specialists to different Latin American laboratories for periods ranging from one to several months. These scientists should help in the definition of sound research objectives and/or cooperate in the research programmes. The same philosophy should be applied to promote the organization of regional PV meetings where specific difficulties of PV research could be discussed. These meetings should combine two types of activities: the exchange of views and news within the Region and the organization of short courses on the theoretical and experimental aspects of PV materials and devices.

3. The possibility of establishing a regional "centre of excellence" with research and teaching activities in photovoltaics should be seriously considered and encouraged. This centre should be the place where researchers and students of the Latin American region could come to perform advanced research, to work on specific PV technologies or to obtain higher degrees. The analysis of the present photovoltaic R&D and industrial activities in Latin America indicates that Brazil is the best candidate to host such a centre. The Laboratory of Photovoltaic Conversion at Unicamp could be a good choice for advanced photovoltaic research and development. The reasons governing this choice are the following: i) it is the most experienced group of the Region; ii) the Laboratory is already acting as a kind of centre of excellence through its cooperative programmes with other Brazilian research groups and with laboratories of Argentina and Colombia, and iii) Campinas is the region where the Brazilian microelectronics industry is established, i.e. this gives an extra opportunity for visitors to know about industrial aspects of the parent industry.

4. United Nations agencies (mainly UNESCO and UNIDO) should establish special programmes for allocating funds: 1) to help active researchers in the field to participate in international PV conferences and 2) for the purchase of books, journals, conference proceedings and technical reports.

B. Cooperation Programmes.

1. UNIDO should study the possibility of establishing programmes to help selected research laboratories that have difficulties with equipment maintenance and with the purchase of inexpensive items like electronic components, special gases, quartz, chemical reagents, etc. The local unavailability of these goods often provokes the complete stop of the research activity for long periods of time. The amounts needed vary from laboratory to laboratory but they do not exceed 10,000 to 20,000 US dollars/year.

2. The United Nations system should study the possibility of promoting "research joint ventures" between laboratories in the Third World and advanced laboratories in the industrialized countries. As an example we can imagine a research laboratory in Latin America collaborating with two or three European groups in a specific PV research programme being sponsored by the European Communities.